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Biological Assessment of Streams Associated with the Northern Training Complex at Fort Knox, Kentucky, August 2000

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Contents

Preface

The study herein was conducted by the Environmental Laboratory (EL), U.S. Army Engineer Research and Development Center (ERDC), in 2000 as part of an environmental assessment of the potential aquatic impacts of proposed changes to the Northern Training Complex, Fort Knox, KY. The purpose was to analyze distribution, density, and community composition of benthic macroinvertebrates in stream habitats representative of those most likely to be affected by erosion and sedimentation related to training.

During the conduct of this study Dr. John W. Keeley was Acting Director, EL; Dr. Dave J. Tazik was Chief, Ecosystem Evaluation and Engineering Division (EEED), EL, and Dr. Alfred F. Cofrancesco was Chief, Aquatic Ecology and Invasive Species Branch (AEISB), EEED. Authors of this report were Dr. Barry S. Payne, AEISB, and Mr. William B. Green, University of Southern Mississippi, Hattiesburg.

At the time of publication of this report, Dr. James R. Houston was Director of ERDC, and COL James S. Weller, EN, was Commander.

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Introduction

Construction and use of proposed training areas in the Northern Training Complex of Ft. Knox has potential to degrade stream habitats. Clearing and maneuvering of treaded vehicles will increase soil erosion rates. Overland runoff will tend to wash disturbed soils into the high gradient headwater streams. During high discharge suspended particles will be carried downstream. Increased deposition of fine-grained particles in streambeds may degrade habitat conditions in the cobble and gravel streambeds typical of this area.

Benthic macroinvertebrates (bottom-dwelling animals without backbones) are sensitive indicators of stream habitat quality, including surrounding land use, water quality, water velocity, and substratum type (Barbour and Stribling 1991: Plafkin *et al.* 1989; Reynoldson *et al.* 1995; Southwood 1977). Thus, the benthic macroinvertebrate aspect of the U.S. Environmental Protection Agency's Rapid Bioassessment Protocol (Barbour *et al.* 1999) was applied to selected streams likely to be affected by proposed improvements of training facilities on Ft. Knox. Emphasis was on description of baseline conditions of water quality, physical habitat characteristics (especially substratum), and macroinvertebrate community composition. Such baseline information allows assessment of relative value of stream habitats, prediction of susceptibility to adverse impacts of construction and use of proposed training sites, and provides a basis for future monitoring.

Healthy riffle communities (permanent streams with good water quality and heterogeneous substratum including much cobble and gravel) tend to support an abundant and diverse fauna including Plecoptera (stoneflies), Trichoptera (caddisflies, especially filter feeding hydropsychids), and Ephemeroptera. Diverse and abundant assemblages of these taxa indicate highly oxygenated water, moderate water velocity, diverse niche space among a mixed substratum of cobble, gravel and sand, and a combination of coarse and fine particulate matter to support shredding and filter-feeding organisms, respectively. Degraded riffle communities (low dissolved oxygen and substantial sedimentation of fine-grained sand, silt, and clay that fills or covers interstices among gravel and cobble) tend not to support these taxa and are often dominated by pulmonate snails (these use air taken at the water surface to meet respiratory demands) and Chironomidae tolerant of both sedimentation and hypoxia.

The macroinvertebrate portion of the RBP is probably most used by states to assess stream health (Southerland and Stribling, 1995). Macroinvertebrate assessments (especially level I to II assessments where most or all taxonomic identifications are done in the field) can be conducted quickly, yet provide a readily interpreted assessment of stream habitat and health understood by most aquatic ecologists. These organisms are relatively immobile; therefore, community composition reacts to local changes in habitat characteristics. They are relatively short-lived; most species complete their life cycle within one year, although a few live several years. Thus, response is rapid to changed conditions. Furthermore, the major taxonomic groups are familiar to most aquatic ecologists, and basic life histories and ecological requirements are moderately well understood.

Sites

Table 1 lists the coordinate locations of all sites. These locations were recorded with a hand-held Global Positioning System. Sites within each stream were numbered from upstream to downstream.

Cedar Point Branch

Steep slopes and small drainage basins characterize streams of Ft. Knox, especially those potentially affected by the Northern Training Complex. Overland runoff affected by Training Areas 1, 2, 3, and 4 is captured by Knob Creek to the north (outside of the northern boundary of the fort) and Cedar Point Branch to the south. Both drainages are high gradient systems; the relatively small drainage of Cedar Point Branch falls entirely within Ft. Knox and collects much of the runoff from proposed Training Areas 1, 2, 3, and 4.

First order streams within the Cedar Point Branch drainage originate at elevations of approximately 820 to 760 feet above mean sea level near the ridge road that roughly parallels Cedar Point Branch to the north. First order streams range in length from approximately 3,000 or 4,000 feet (those draining from the north) to 6,000 feet (the headwater of Cedar Point Branch in its easternmost reach). Thus, stream slope is approximately 7% in the steeper portions of the upper parts of this (i.e., the streambed elevation decreases 7 feet per 100 feet of stream length. Two second order streams are formed at elevations of 600 feet (northern tributaries) and 625 feet (eastern tributaries); these two streams flow over distances of only 1,800 feet (northern system) and 3,000 feet (eastern system) before joining to form the upstream origin of Cedar Point Branch's third order reach at an elevation of approximately 545 feet. Thus, stream slope of the second order tributaries ranges from approximately 2.7% to 3.0%. Cedar Point Branch remains a third order channel until its confluence with the Salt River at an elevation of approximately 400 feet (Photograph 1). Cedar Point Branch was sampled in the middle to lower part of its third order reach at approximately elevation 420 to 440 feet. Stream slope in the reach sampled was approximately 0.67% (a drop in streambed elevation of 20 feet per 3000 feet of stream length).

Even at this relatively low elevation within the third order portion of Cedar Point Branch, the stream is intermittent due to the very high stream slopes of its first and second order tributaries. The only permanent aquatic habitats were in pooled reaches along the cut bank side of the stream. These pooled reaches ranged in length from 50 to 200 feet and were separated by much greater distances of dry streambed. Stream banks were approximately 6 feet high. High water marks were at least 7 feet up the trunks of shoreline trees. Bank-to-bank stream width was approximately 30 to 50 feet and the dry bed was predominately well scoured cobble and gravel. These characteristics indicate occasional high discharge and swift flow that must characterize this stream during seasonal high flows.

Castleman Creek

This creek drains from the area of Shepherds Cemetery to the north of the fort boundary near Shepherdsville, KY. Castleman Creek is a third order stream in the portion that extends from approximately the Fort Boundary to its entry into Duck Lake. The second order streams that form Castleman Creek are short (1000 and 1500 feet) with slopes of 1.3 and 1.0%. We sampled four sites in the upper to middle portion of its third order reach, where slope equals approximately 1.0% or slightly less and at a single site just upstream of Pitts Point Road and Duck Lake where stream slope is only 0.25%. The upper four sites were all intermittent stream habitat. Pooled areas ranged from 100 to 200 feet long. Dry stream reaches between pooled areas were slightly longer than the pooled reaches (i.e., this stream was almost a permanent stream in this reach). Stream flow was barely detectable but very low (<0.1 foot per second). Bank height was approximately 5-6 feet and bank-to-bank stream width was approximately 30 ft. The streambed was a mix of cobble, gravel, sand, and scoured clay. A few small boulders protruded from the bed; these were well rounded, indicative of scouring flow that characterizes this stream at high flow.

Castleman Creek is useful as a reference stream in relation to construction and training impacts. No overland runoff from Training Areas 1-5 will end up in Castleman Creek although the Creek is in the general proximity of these areas. The creek is barely outside the northern edge of the proposed Wilcox Range (Training Area 6).

Woodland Creek

This creek was inspected from the upper to lower reaches of its length as a third order stream (the highest order it attains before draining into Duck Lake closely adjacent to Castleman Creek). It is a dry streambed at low flow throughout its third order reach. Thus, no samples of macroinvertebrates were collected. Scour holes formed around the root wads of large bankside trees provided the only aquatic habitat. These holes typically held only a few gallons of water; dry streambed typically extended several hundred feet between these minor accumulations of water. Despite its dry condition, the bed of Woodland Creek is comprised of large gravel and small cobble, bank-to-bank width is approximately 30 feet, and bank height is approximately 3 feet. The streambed indicates that scouring conditions exist during seasons of high discharge.

Woodland Creek drains approximately half the area that is drained by Castleman Creek. Otherwise, the streams appear similar on a USGS quad map. Overland runoff from Training Area 5 (Maneuver, Drop Zone, Landing Zone) to the east will pass through Woodland Creek. The proposed Wilcox Range (Training Area 6) will directly affect the lowermost portion of Woodland Creek.

Mud Creek and Tributary

Three sites were sampled in the Mud Creek drainage. Two sitė were in the tributary of Mud Creek west of Trautman Cemetery. This tributary is a first order stream at that point and has coursed 12,000 feet down the narrow valley that parallels the Dug Hill Road. This tributary emanates at elevation 780 ft and falls to 450 ft where we sampled it as it exits the steep valley and enters onto the alluvial floodplain of the Salt River.

The stream is intermittent and narrow at the upper sites sampled. Bank-to-bank width measured only 15 feet. The streambed was a sand, silt, and gravel with some cobble. Bank height was approximately 3 feet. Intermittent pools consisted of short narrow bands of water along the cut bank that were only a foot or two wide and 10 to 20 feet long or scour holes below root wads of large trees on the bank. Distances of several hundred feet separated such pooled reaches.

The lower site (slightly upstream of Pearl Pond) was simply a small pool in a depressional area of the streambed. The bed at this point is ill defined (simply the lowest points along a meandering line through a broad alluvial floodplain).

The upper drainage of Mud Creek may be indirectly affected runoff during construction of Training Area 9 (an Airstrip). The lower portion of Mud Creek courses across the center of the proposed Wilcox range (Training Area 10), through Pearl Pond, and into the Salt River.

Wilcox Lake #3 and Duck Lake

Both reservoirs are shallow and soft-bottomed lakes with extensive dense growth of submersed vegetation (mostly *Chara*) in the littoral zone. Duck Lake is approximately 10 times the area of Wilcox Lake #3. Duck Lake receives intercepts the drainage of both Woodland Creek and Castleman Creek shortly after their confluence in route to the Salt River approximately 1000 ft downstream of Duck Lake. Wilcox Lake number three is an impoundment along a minor first order tributary of lower Woodland Creek. Both lakes fall within the upper part of the proposed Wilcox Digital Tank Range; both represent shallow lentic habitat along the Salt River floodplain typical of that to be affected by the proposed tank range.

Methods

A reconnaissance-level survey of stream habitat and aquatic macroinvertebrates was made at each site according to the Rapid Bioassessment Protocol (Barbour *et al.* 1999). Essentially, the available aquatic habitat at each location was assessed with respect to stream morphology, water quality, inorganic and organic substrate conditions, and relative abundance and richness of macroinvertebrate taxa. Water quality (temperature, pH, dissolved oxygen, and specific conductance) was assessed using a portable Hydrolab.

Each substratum type (i.e., cobble, gravel, sand, clay, or leaf litter) was sampled at least four times each using a standard D-frame net (0.5 mm mesh) pulled gently through the uppermost layer of substratum (i.e., barely digging in) the streambed surface. Each net pull through substratum was over a distance of approximately 1.75 feet. Leaf litter was sampled by jabbing the net into aggregated litter on the streambed. Organisms on several larger pieces of cobble were brushed into the net. Thus, samples were a composite representation of multiple habitats per site.

Macroinvertebrates were sorted from sediment and litter in a white enamel pan, identified in the field to the lowest practical level, and their relative abundance was noted according to the RBP field data sheet for macroinvertebrates. A small sample of sand and gravel was taken from each stream, preserved in 75 % ethanol with a small amount of eosin dye, and returned to the laboratory for inspection using a dissecting microscope. This allowed more precise identification of some taxa than was possible in the field and allowed very small macroinvertebrates, including early instars of some insect larvae too small to be seen in the field with a naked eye or hand lens. In addition, leaf litter and FPOM samples were collected from Cedar Point Branch, preserved, and returned to the lab for similar inspection.

Macroinvertebrates were collected from lake margins by sweeping the D-frame net through submersed vegetation and gently through the top layer of the mud bottom (8 sweeps per lake). Identification and enumeration of invertebrates was done in the field as described above; subsamples of plant debris and detritus were preserved for more detailed inspection in the laboratory.

Results

Cedar Point Branch

The upstream site (Site 1) in this creek was a narrow, linear pool along the right descending bank (Photograph 2). This pool along the cut bank was the deepest part of the streambed. The pool was approximately 150 feet long, averaged 2 to 4 feet wide, and water depth averaged 0.5 ft. Maximum depth was approximately 1.5 feet at the downstream end of the pool in a scour hole formed below a large tree. Substrate was mostly cobble with a substantial amount of gravel and sand with some organic debris (Table 2). Coarse particulate organic matter (CPOM, coarse particulate matter comprised of tree leaves, wood, and twigs) and organic muck (FPOM, fine particulate organic matter resulting from degradation of CPOM) were present in small quantity along the bottom of the pool. The remaining (dry) streambed at this site was a flat cobble riffle that extended from the pool to the left descending bank (Photograph 2).

Characteristics of the entire streambed width were noted to assess habitat features during high flow. Instream cover was optimal, with a mix of older snags and logs, cut banks, heterogeneous cobble and gravel. Cobble and gravel were not embedded in finer substrate to an extent that limited diversity of niche space. Sediment deposition did not appear to be substantial. Banks were stable and forest provided an extensive and diverse canopy and extensive riparian protection. Riffles and runs were very frequent (virtually continuous) in this stream reach; scour holes associated with large trees along the cut bank and large snags provided the main velocity refugia during high flow.

Site 2 was approximately 300 feet downstream of Site 1 and was a long (150 ft), shallow (0.5 ft), wide (10 ft) pool along the left descending bank (Photograph 3). The left bank was a vertical cliff of clay and substratum was "bedrock" of scoured, hard clay. Sand, gravel, and cobble were present along the right margin and both ends of this pool. Extensive FPOM littered the hard clay (Photograph 4). CPOM was abundant in a relatively deep pool (2.5 ft) at the upstream end of the entire pool. Water velocity was 0 ft/sec.

Water quality measurements at both sites indicated cool temperature, moderately high specific conductance, low dissolved oxygen (moderate hypoxia), and near neutral pH (Table 3). Water was clear (not turbid) and only slightly stained (tannin stain from leaf litter decomposition). There was no evidence of organic pollution (odors, oils, or deposits). A slight hydrogen sulfide smell, due to localized anoxia, was apparent only when sampling leaf litter.

The benthic macroinvertebrate community at both sites was neither rich in taxa nor numerically abundant (Table 4). Five major taxonomic groups were evident in the field, with true bugs (Hemiptera) numerically dominant. Hemiptera were clearly dominated by one small aquatic taxon and one abundant species of water striders (*Notonecta* sp.). A single species of decapod (crayfish, *Orconectes* sp.) was numerically common to abundant; in terms of biomass decapods dominated the community. Crayfish were more abundant at Site 2 than Site 1. Chironomidae (bloodworms) were common. Oligochaetes were rare but present. A single snail of the pulmonate family Physidae was obtained at Site 1. Despite periphtyon growth on the scoured clay bottom at Site 2, no snails were found at that location. Only a few trichopterans were evident on larger cobble. Despite the abundance of cobble and gravel, no ephemeropterans or plecopterans were present.

Laboratory analysis of leaf litter, FPOM, and gravelly sand revealed an abundance of very small Chironomidae that were not evident during field processing of samples (heavily dominated by bloodworms of the subfamily Chironominae) (Table 5). These were most abundant in leaf litter and fine detritus, but were also evident in moderate abundance in sand and gravel. Two isopod crustaceans (both *Lirceus* sp.) and a few copepods were obtained in samples returned to the laboratory.

Cyprinids, darters, and salamander newts were abundant at both sites. Fish taxa and amphibians were heavily dominated by or entirely comprised of a single species.

Castleman Creek

Castleman Creek was sampled at four locations. The three upstream sites (Sites 1-3, all in the valley leading toward Shepherd Cemetery) were similar in that the streambed at these locations was essentially an erosional riffle with a heterogeneous mix of cobble, gravel, sand, and hard clay at these three sites (Table 2; Photographs 5, 6 and 7). At each site, pools with accumulated leaf litter were associated with scoured holes below root wads of large trees along the bank. In contrast, the downstream site (Site 4) was on the alluvial floodplain of the Salt River just upstream of Duck Lake and Pitts Point Road; this site was depositional with deep (and anoxic) deposits of soft clay, silt, and leaf litter (Table 2; Photograph 8).

Bank-to-bank width at Sites 1-3 was approximately 20-30 ft. Intermittent pools providing aquatic habitat varied among sites from 100 to 200 ft in length, averaged 3 to 6 ft in width, and had average depth of 0.5 ft. The deepest pooled areas were in scoured holes that measured as deep as 2.5 ft. The dry portion of the streambeds tended to be dominated by large gravel and small cobble. Substantial deposition of sand among these larger particles created a more consolidated riffle than in Cedar Point Branch. High water marks were not apparent in the surrounding woods; the top bank of the stream was approximately 6.5 feet higher than the streambed. Well-rounded boulders jutted from the streambed in some locations and indicated that scouring flow is common in this stream. Canopy coverage was extensive, but enough light penetrated to support periphyton growth on cobble. There was no evidence of organic pollution. A slight hydrogen sulfide smell was associated with the more depositional areas in each intermittent pool. A small amount of debris of human origin was present (e.g., machine parts, pieces of concrete slabs, and old bricks).

The streambed at Site 4 was formed as a 25 ft wide channel through alluvial floodplain soils. The forest canopy was extremely dense at Site 4. The anoxic substratum at Site 4 smelled strongly of hydrogen sulfide when disturbed. There was no evidence of organic pollution.

Water quality measurements are summarized in Table 3. Water temperature was slightly greater than 20°C at Sites 1-3 and slightly less than 20°C at Site 4 (reflecting the very dense canopy at Site 4). Conductance was moderate at all sites. Dissolved oxygen ranged from 1.9 to 3.7 mg/L at Sites 1-3 and equaled 1.2 mg/L at Site 4. Conductance was moderate 0.265 to 0.334 mS/cm. Measurements of pH indicated a near neutral condition (6.8 to 7.4). Water was clear at all sites, although sediment resuspended with only minor disturbance at Site 4. Water at Site 4 was moderately tannin-stained.

The macroinvertebrate community was similar at Sites 1-3 and contrasted with conditions at Site 4 (Table 6). Decapods (the same *Orconectes* sp. as in Cedar Point Branch) were abundant at Sites 1-3. Hemipterans were also abundant at these sites (approximately 4 species of small aquatic species were evident, with one being heavily dominant). Water striders (*Notonecta* sp.) were common on the water surface. Taxa common to rare at Sites 1-3 included Chironomidae, Trichoptera, and Coleoptera. In contrast, Chironomidae dominated the fauna at Site 4, where neither decapods nor hemipterans were observed. Oligochaetes and amphipods were common to rare at Site 4. Laboratory samples of substratum did not add to these estimates of diversity in Castleman Creek (Table 5).

Woodland Creek

Two sites were investigated in this drainage. Both were dry. The upstream site was a 30 ft wide channel of large and medium cobble with some gravel and sand (Photograph 9). Bank height was approximately 2 to 3 feet. Scour holes below large trees at the edge of the channel provide the only pool habitat in an otherwise continuous riffle. No water was found even in these scour holes. The downstream site (Site 2; Photograph 10) was near Pitts Point Road in the same general area as the downstream site in the closely adjacent Castleman Creek. The channel was very similar to that at Site 1. One scour hole held a few gallons of water; however, the near total lack of permanent water precluded sampling of Woodland Creek. The cobble streambed was evidence that this creek occasional conveys swift scouring flow despite being dry during low flow seasons.

Mud Creek and Tributary

Two sites (Sites 1 and 2) were sampled in the western tributary of Mud Creek where the tributary emerges from a steep valley onto the alluvial floodplain of the Salt River. A third (Site 3) and more depositional site was sampled further downstream approximately 2000 feet upstream of where Mud Creek broadens into Pearl Pond.

Site 1 was a narrow pool along the left descending bank, approximately 120 ft long, 3 ft wide, and 6.5 feet deep (Photograph 11). The stream channel was only 10 to 15 ft wide; bank height was 3 to 4 feet. Channel substratum was a mix of some cobble with much gravel, silt, and soft clay (Table 2). Clay and leaf litter deposits smelled of hydrogen sulfide when disturbed. There was no evidence of organic pollution. Surrounding woodlands were second growth on abandoned farmlands (old barbed wire fencing ran along the left descending bank).

Site 2 was approximately 300 ft downstream (and was the next available pool of water). This site was a deep (3 ft) but small (4 ft diameter) scour hole under a root wad of large tree along the left descending bank (Photograph 12). Substrate was clay with dense leaf litter (Table 3). The substrate smelled strongly of hydrogen sulfide upon sampling.

Water quality at these two sites was similar. Temperature was 20.3 °C at both locations, conductance was moderately high, dissolved oxygen was low, and pH was slightly above neutral.

Macrobenthos at Site 1 included moderately abundant Hemiptera and Coleopetera, common oligochaetes, decapods, and chironomids, and a few trichopterans (Table 7). Laboratory processing of sand and gravel subsamples revealed an abundance of very small (early instar) ephemeropterans of the family Baetidae that were not observed during field processing of samples as well as many very small physid snails (Table 5). Dipterans other than chironomids included Culicidae, Ceratopogonidae, and Chaoboridae, although chironomids (Chironominae) were heavily dominant. Hemipterans included representatives of the family Gerridae, Corixidae, and Veliidae. Coleopterans included Dytiscidae and Curculionidae. Macrobenthos at Site 2 were dominated by hemipterans

(Table 7). Decapods were common, and gastropods (physids), bivalves (sphaeriids), and coleopterans were rare. Cyprinids, darters, and newts were present at both sites.

Site 3 was a shallow muddy pool in a depression along the lower stream channel (Photograph 13) that meanders through the broad alluvial and forested floodplain of the creek as it approaches Pearl Pond (Photograph 14). Oligochaetes, decapods (the same *Orconectes* sp. observed at all sites), gastropods (pulmonate snails of the genus *Helisoma*), and chironomids were all common but not abundant (Table 7). A single sphaeriid bivalve was also found. Laboratory processing of a subsample of the soft sediment and leaf litter at this location revealed several very small (recently released young) sphaeriid bivalves, indicating that this taxon is common at this site (Table 5). Many small chironomids (Chironominae) were also found. Isopoda, Hemiptera, Coleoptera, Odonata, and Megaloptera were orders that were rare but present in the sample analyzed in the laboratory.

Duck Lake and Wilcox Lake #3

The littoral margins of these lakes, the focus of sampling, consisted of macrophytes (heavily dominated by the submersed macrophytic algae, *Chara*) growing from a soft mud-muck bottom. Plants at Duck Lake (Photograph 15) were healthy and green, while those in Wilcox Lake (Photograph 16) were blackened by anaerobic conditions. The bottom at both lakes smelled strongly of hydrogen sulfide when disturbed.

Water quality differed with respect to dissolved oxygen in the two lakes (Table 3). Duck Lake had moderately high dissolved oxygen (5.71 mg/l); Wilcox Lake #3 was hypoxic (1.33 mg/l). Duck Lake is approximately 10 times the area of Wilcox Lake #3. Woodland Creek and Castleman Creek both flow through Duck Lake; Wilcox Lake #3 is fed by a very short first order tributary of Woodland Creek. Average retention time of water is Duck Lake is probably considerably less than that in Wilcox Lake, which probably contributes to the observed dissolved oxygen differences.

These water quality differences were reflected by the abundance and diversity of macroinvertebrates in the littoral zones of the two lakes (Table 8). From field processing of samples, only amphipods, gastropods, and hemipterans were common in the more stressful habitat provided by Wilcox Lake #3. In contrast, abundant taxa in Duck Lake included Amphipoda, Bivalvia, Hemiptera, Coleoptera, Tipulidae, and Culcidae. In addition, common taxa included Oligochaeta, Anisoptera, Zygoptera, Chironomidae, and Ephemeroptera.

The large amount of plant debris and detritus in samples hindered field inspection of samples. Laboratory inspections of subsamples from each lake generally confirmed inter-lake differences in diversity and abundance observed in the field, but added to the diversity estimates for both lakes (Table 5). However, small Chironomids clearly were numerically dominant in Wilcox Lake #3, and oligochaetes (both Naididae and Tubificidae) were common and some ephemeropterans (both Baetidae and Caenidae) and odonates (Coenagrionidae and Libellulidae) were present. Abundance and, for most taxa, diversity of Amphipoda, Diptera, Ephemeroptera, Hemiptera, Coleoptera, and Odonata was greater in Duck Lake than in Wilcox Lake #3.

Discussion

Baseline conditions in these first to third order streams are such that substantial adverse impacts to stream biological resources are not anticipated. Many of the stream sites sampled were characterized by a heterogeneous mix of cobble and gravel that was not much buried or surrounded by smaller particles (sand and silt). In general, this is an ideal condition for a diverse and abundant riffle fauna indicative of a healthy stream (Plafkin *et al.* 1989; Southwood 1977). Scouring flow during storms and rainy seasons keep streambeds in excellent condition (and create channels much wider than typically associated with intermittent streams). However, long periods without flow severely limit the biological value of these streams. The steep slopes and relatively small drainage areas of the stream systems associated with the Northern Training Complex preclude permanency of lotic conditions necessary to support abundant and diverse stream life. Thus, although increased sedimentation associated with proposed construction and training activities may alter streambeds, intermittent flow is the limiting factor to these streams' biological value. In addition, scouring flows during rainy seasons and major storms may be sufficient (based on the cobble beds if these intermittent stream channels) to transport most sand onto the alluvial floodplain of the Salt River (Castleman Creek, Woodland Creek, and Mud Creek) or directly into the Salt River (e.g., Cedar Point Branch which has a short course over the Salt River floodplain).

Maneuver areas, drops zones, and landing zones proposed to the northwest of the Wilcox Range are located such that potential impacts to streams (especially Cedar Point Branch) must be considered. Although increased sedimentation of streams may occur, even in lower Cedar Point Branch stream intermittency limits biological habitat value. Without permanent flow, most aquatic macroinvertebrates cannot complete their life cycles. Additionally, stream intermittency greatly reduces dissolved oxygen levels. Without continuous or frequent flushing flows, community respiration leads to hypoxic conditions tolerated mainly by taxonomic groups that are typical of stressed rather than healthy streams. Macroinvertebrate abundance, perhaps with the exception of crayfish, chironomids, and some small hemipterans was low to moderate. Even the more abundant, tolerant taxa (such a chironomids and pulmonate snails) tended not to be as abundant as would be expected in permanent stream habitats. Certainly, diversity was low at all stream sites assessed -- including sites in Cedar Point Branch, Castlemen Creek, Woodland Creek, and Mud Creek.

A macroinvertebrate assessment of Mill Creek conducted in May 1982 (Kentucky Division of Water, 1984) included one site (their site 30-1) upstream of organically polluted reaches of that stream which was represented by the type of diverse macroinvertebrate community expected in permanent lotic habitats in this region of Kentucky. Their collection from a permanent stream site with a cobble and gravel substratum included many more taxa and functional feeding groups than were present in our collections from intermittent streams. Ephemeroptera (mayflies) were moderately abundant at the site in Mill Creek and included representatives of the families Baetidae, Caenidae, Ephemeridae, Heptageniidae, and Oligoneuriidae. In contrast, only one family of mayflies was represented at only one stream site in the present study. Plecoptera (stoneflies of the family Perlidae) were common at the Mill Creek site. None were obtained in the present study. Filter-feeding hydropsychid caddisflies (Trichoptera, family Hydropsychidae) were abundant and dominated the fauna at the Mill Creek site. Only a few Trichoptera (and no hydropsychids) were obtained in the present study. Such diversity and abundance of trichopterans, plectopterans, and ephemeropterans typifies a cobble streambed that has permanent flow of well-oxygenated water (Plafkin *et al.* 1989). Such communities, indicative of healthy lotic habitats (Barbour *et al.* 1999; Plafkin *et al.* 1989), were not encountered in streams affected by the Northern Training Complex, a direct result of stagnancy and associated hpoxia in isolated pools that provided the only permanent aquatic habitat.

Probably the most susceptible stream system potentially affected by project alternatives is Cedar Creek, which flows though the southern portion and then along the western boundary of the present Cedar Creek Range before emptying into the Rolling Fork River. This stream is a cobble and gravel channel with permanent flow; although not included in the present assessment of macroinvertebrate communities, Cedar Creek is likely to support a community similar to that observed by Kentucky Division of Water in Mill Creek (Kentucky Department of Water 1982). Clearing and construction required to substantially enlarge and upgrade the existing range would directly affect Cedar Creek. Channel alteration and sedimentation are likely to result in degradation of physical and biological conditions in Cedar Creek.

Upgrading of the other existing tank range, the Yano Range, would result in minor impacts to stream resources. This range is on the Rolling Fork River floodplain. The Rolling Fork River crossed the middle of the range flowing from the southeast to the northwest. First order creeks on the present range are few, intermittent and flow directly into the Rolling Fork. The Rolling Fork (approximately a sixth order stream at this location) is a turbid river with a simple trapezoidal channel cut into steep clay banks. Thus, virtually the Yano Alternative will affect no instream habitat other than the Rolling Fork River. The amount of water discharged from the range into to the Rolling Fork River is a minor portion of the river's discharge at this location. Further the turbid nature of the river and its incision into clay should further minimize impacts of sedimentation or suspended sediment input.

Streams directly affected by the proposed Wilcox Range are small, low gradient systems represented by conditions found in lower Mud Creek and Cattleman Branch. The greatest biological value of these low gradient stream courses is where they are impounded (such as at Pearl Pond and Duck Lake). Biological resources in the stream channels flowing into these impounded areas are not diverse or abundant due to the intermittency and stressfully low dissolved oxygen.

In summary, the macroinvertebrate communities in streams sampled in the Northern Training Complex in August 2000 was neither abundant nor diverse. These communities were primarily limited by intermittency of stream flow and associated hypoxia. Thus, instream biological impacts of construction and use of proposed training areas is not likely to be substantial. If appropriately sized riparian corridors are left to protect the edges of streams, then physical changes to streambeds can be minimized (Barton *et al.* 1985). This would allow maximum biological use of stream channels during sustained periods of high to moderate flow (i.e., perhaps allowing multivoltine insects to complete their relatively short life cycles). Regardless, indirect effects of sedimentation on aquatic communities in intermittent streams are of minor concern relative to direct effects on forests and wetlands.

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Table 1. Geographic coordinates of sampled sites and other reference points.

Stream/Lake	Site	Latitude	Longitude
Cedar Point Branch	1	37.977652	85.87724
	2	37.97595	85.87832
Castleman Creek	1	37.98580	85.78853
	2	37.98349	85.78700
	3	37.98249	85.78693
	4	37.97248	85.78132
Woodland Creek	1	37.97322	85.79481
	2	37.96977	85.78266
Mud Creek and Trib.	1	37.95138	85.80912
	2	no record (300 ft east of site 1)	
	3	37.95129	85.79811
Duck Lake	1	37.97314	85.77475
Wilcox Lake #3	2	37.96751	85.78305
Pearl Pond at Pitts Point Road		37.95148	85.79337
Salt River Bridge		37.99226	85.92202

Table 2. Summary data on inorganic and organic substrate composition.

	% composition by particle size					% occurrence in stream	
Site	cobble	gravel	sand	silt	clay	CPOM	FPOM
Cedar Point Branch							
Site 1	70	10	5	5	5 (h)	10	5
Site 2	10	10	10		70 (h)	5	65
Mud Creek							
Site 1	5	30	10	30	25 (d)	10	
Site 2					100 (d)	30	
Site 3				50	50 (d)	80	
Castleman Creek							
Site 1	25	45	30			20	
Site 2	20	30	40	10	10(h)	5	
Site 3	30	30	30		10(h)	5	
Site 4		10	10		80 (d)	10	20
Duck Lake					100 (d)	10	90
Wilcox Lake #3					100 (d)	10	90

Table 3. Summary of water quality measurements.

Site	Temperature (°C)	Conductance (mS/cm)	D.O. (mg/L)	pH
Cedar Point Branch				
Site 1	18.4	0.545	2.19	7.18
Site 2	17.6	0.590	1.90	6.93
Mud Creek				
Site 1	20.3	0.447	1.54	7.27
Site 2	20.3	0.437	0.63	7.08
Site 3	20.2	0.452	0.68	8.14
Castleman Creek				
Site1	20.6	0.288	1.91	6.99
Site 2	20.5	0.271	3.74	7.41
Site 3	21.1	0.265	2.64	7.27
Site 4	19.6	0.334	1.17	6.82
Duck Lake	26.0	0.227	5.71	8.95
Wilcox Lake #3	24.7	0.170	1.33	7.14

Table 4. Relative abundance of macroinvertebrates in Cedar Point Branch.

Taxon	Absent	Rare	Common	Abundant
Site 1:				
Oligochaeta		x		
Decapoda			x	
Gastropoda		x		
Hemiptera				x
Chironomidae			x	
Trichoptera		x		
Site 2:				
Oligochaeta	x			
Decapoda				x
Gastropoda	x			
Hemiptera				x
Chironomidae			x	
Trichoptera		x		

Table 5. Macronvertebrates identified in selected subsamples preserved and returned to the laboratory.

	Cedar Point Branch CPOM	Cedar Point Branch Sand & Gravel	Cedar Point Branch FPOM	Mud Creek Site 3	Castleman Creek Site 1	Castleman Creek Site 2	Duck Lake	Wilcox Lake # 3
Amphipoda							28	4
Copepoda	3	1						8
Isopoda				2				
Asellidae								
Lirceus sp	2							
Bivalvia								
Sphaeridae				10				
Diptera								
pupae	1		1				20	
Chironomidae	131	18	38	28	18	2	176	160
Culicidae					1			4
Ceratopogonidae				5	2		4	8
Chaoboridae					1			
Tabanidae							8	
Stratimyidae							4	
Oligochaetae								
Tubificidae	3						32	20
Naididae							4	40
Trichoptera						1		
Ephemeroptera								
Baetidae					52		156	16
Caenidae							28	12
Hemiptera								
Gerridae					3		8	
Belostomatidae							8	
Corixidae					1			
Veliidae					2			

Notonectidae								
Notonecta sp.				1				

Table 5. (Continued)

	Cedar Point Branch			Mud Creek	Castleman Creek			
	CPOM	Sand & Gravel	FPOM	Site 3	Site 1	Site 2	Duck Lake	Wilcox Lake # 3
Coleoptera								
immature								4
Dytiscidae				1	3			
Curculionidae					1			
Elmidae				1				
Haliplidae								
Peltodytes sp.							4	
Noteridae								
Hydrocanthus sp.							4	
Hydrophilidae								
Tropisternus sp.							4	
Odonata								
Gomphidae				1				
Coenagrionidae							36	16
Libellulidae							32	24
Megaloptera								
Sialidae								
Sialis sp.				2				
Gastropoda								
Physidae					16			4
Turbellaria								4
Cladocera								8

Table 6. Relative abundance of macroinvertebrate taxa in Castleman Creek.

Taxon	Absent	Rare	Common	Abundant
Site 1:				
Oligochaeta	x			
Decapoda				x
Gastropoda	x			
Bivalvia	x			
Hemiptera			x	
Coleoptera		x		
Chironomidae		x		
Trichoptera		x		
Site 2:				
Oligochaeta	x			
Decapoda				x
Gastropoda	x			
Bivalvia	x			
Hemiptera	x			x
Coleoptera	x			
Chironomidae			x	
Trichoptera			x	
Site 3:				
Oligochaeta	x			
Decapoda				x
Gastropoda	x			
Bivalvia	x			
Hemiptera				x
Coleoptera	x			
Chironomidae			x	
Trichoptera		x		
Site 4:				
Oligochaeta			x	
Amphipoda		x		
Decapoda	x			
Gastropoda	x			
Bivalvia	x			
Hemiptera	x			
Coleoptera	x			
Chironomidae				x
Trichoptera	x			

Table 7. Relative abundance of macroinvertebrate taxa in Mud Creek

Taxon	Absent	Rare	Common	Abundant
Site 1:				
Oligochaeta			x	
Decapoda			x	
Gastropoda	x			
Bivalvia	x			
Hemiptera				x
Coleoptera				x
Chironomidae			x	
Trichoptera		x		
Site 2:				
Oligochaeta	x			
Decapoda			x	
Gastropoda		x		
Bivalvia		x		
Hemiptera				x
Coleoptera		x		
Chironomidae	x			
Trichoptera	x			
Site 3:				
Oligochaeta			x	
Decapoda			x	
Gastropoda			x	
Bivalvia		x		
Hemiptera	x			
Coleoptera	x			
Chironomidae			x	
Trichoptera	x			

Table 8. Relative abundance of macroinvertebrates in Duck Lake and Wilcox Lake #3.

Taxon	Absent	Rare	Common	Abundant
Duck Lake:				
Oligochaeta			x	
Decapoda	x			
Amphipoda				x
Gastropoda				x
Bivalvia				
Anisoptera			x	
Zygoptera			x	
Hemiptera				x
Coleoptera				x
Tipulidae				x
Culcidae				x
Chironomidae			x	
Ephemeroptera			x	
Trichoptera	x			
Wilcox Lake #3				
Oligochaeta		x		
Decapoda	x			
Amphipoda			x	
Gastropoda			x	
Bivalvia	x			
Anisoptera	x			
Zygoptera	x			
Hemiptera			x	
Coleoptera	x			
Tipulidae	x			
Culcidae	x			
Chironomidae	x			
Ephemeroptera	x			
Trichoptera	x			

Photograph 1. Upstream view of the Salt River showing rugged terrain along the right descending bank that represents the area drained by Cedar Point Branch.

Photograph 2. Upstream view of Site 1 in Cedar Point Branch showing pooled water along cut bank and cobble of dry streambed.

Photograph 3. Downstream view of Site 2 in Cedar Point Branch, a wide and shallow pool along the base of the vertical cliff that forms the left descending bank.

Photograph 4. Fine Particulate organic matter (FPOM) accumulated in Site 2 in Cedar Point Branch.

Photograph 5. Downstream view of Site 1 in Castleman Creek.

Photograph 6. Upstream view of Site 2 in Castleman Creek.

Photograph 7. Downstream view of Site 3 in Castleman Creek showing herbaceous and young woody vegetation growing in dry cobble streambed.

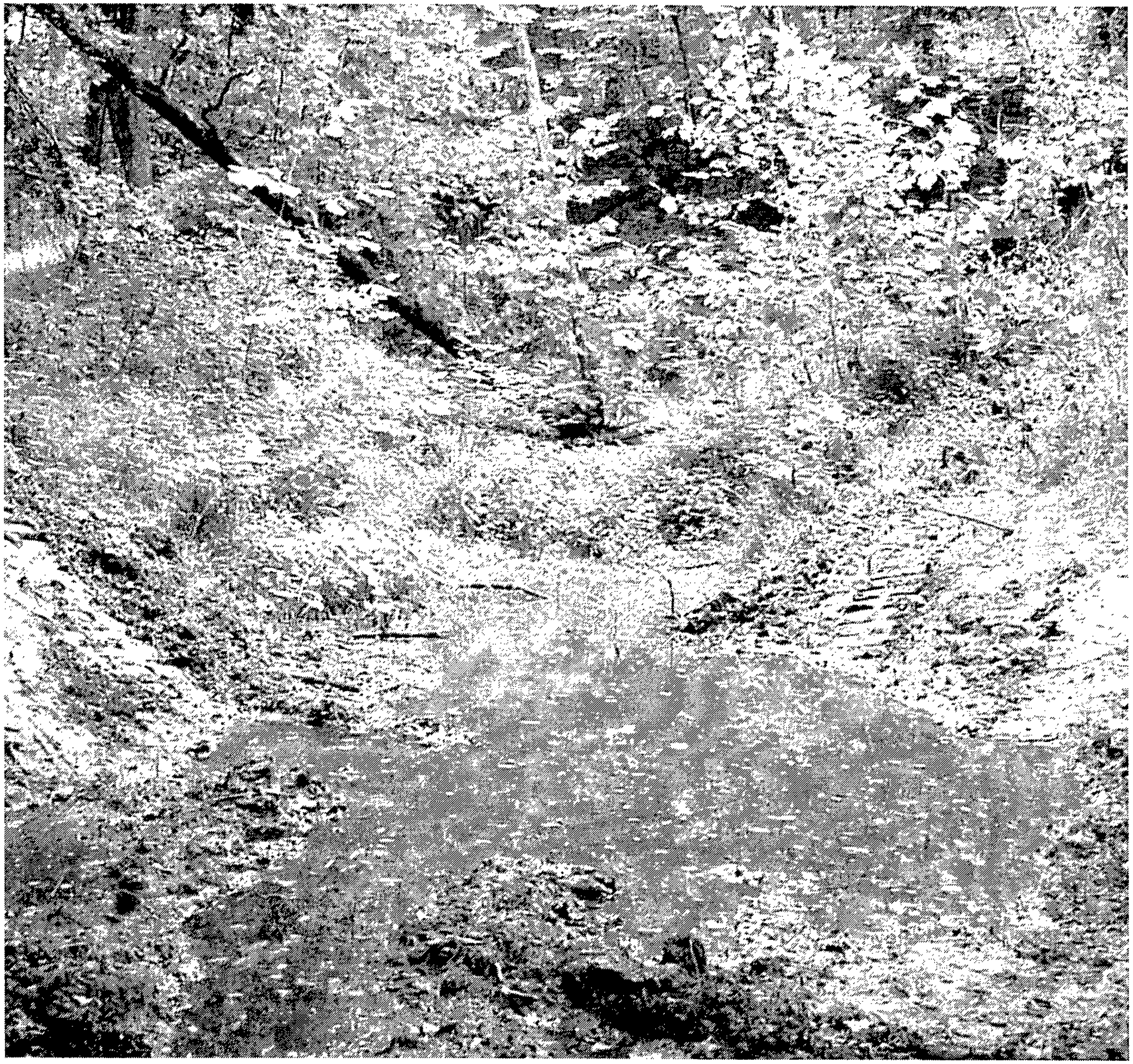
Photograph 8. Downstream view of Site 4 in Castleman Creek with the sunny opening downstream indicating the location of Pitts Point Road.

Photograph 9. Upstream view of Site 1 in Woodland Creek showing the dry gravel and cobble streambed and a small scoured depression at the base of a large tree on the left descending bank.

Photograph 10. Downstream view of Site 2 in Woodland Creek showing dry gravel and cobble streambed.

Photograph 11. Downstream view of Site 1 in Mud Creek tributary showing slightly turbid pooled water mainly along the left descending bank.

Photograph 12. Upstream view of Site 2 in Mud Creek tributary   a pool of water in a scoured area where the stream bends between two large trees on the banks.



Photograph 13. Downstream view of Site 3 in Mud Creek, a pooled depression in the meandering streambed through a forested alluvial floodplain upstream of Pearl Pond.

Photograph 14. Pearl Pond on Mud Creek downstream of Pitts Point Road.

Photograph 15. Upstream portion of Duck Lake.

Photograph 16. Upstream view of Wilcox Lake # 3.

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13.ABSTRACT *(Maximum 200 words)*

Construction and use of proposed training areas in the Northern Training Complex of Fort Knox have the potential to degrade stream habitats. Clearing and maneuvering of treaded vehicles will increase soil erosion rates. Overland runoff will tend to wash disturbed soils into the high-gradient headwater streams. During high discharge, suspended particles will be carried downstream. Increased deposition of fine-grained particles in streambeds may degrade habitat conditions in the cobble and gravel streambeds typical of this area.

The benthic macroinvertebrate aspect of the U.S. Environmental Protection Agency's Rapid Bioassessment Protocol was applied in August 2000 to selected streams likely to be affected by proposed improvements of training facilities on Fort Knox. Emphasis was on description of baseline conditions of water quality, physical habitat characteristics (especially substratum), and macroinvertebrate community composition. Such baseline information allows assessment of relative value of stream habitats and prediction of susceptibility to adverse impacts of construction and use of proposed training sites and provides a basis for future monitoring.

Macroinvertebrate communities in streams sampled in the Northern Training Complex were neither abundant nor diverse. These communities were limited primarily by intermittency of streamflow and associated hypoxia. Thus, instream biological

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impacts of construction and use of proposed training areas are not likely to be substantial. If appropriately sized riparian corridors are left to protect the edges of streams, then physical changes to streambeds can be minimized. This would allow maximum biological use of stream channels during sustained periods of high to moderate flow (i.e., perhaps allowing multivoltine insects to complete their relatively short life cycles). Regardless, indirect effects of sedimentation on aquatic communities in intermittent streams are of minor concern relative to direct effects on forests and wetlands.